Heavy Vehicle Propulsion Materials

Durability and Reliability of Porous Cordierite Diesel Particulate Filters

Background

Diesel engines are the most efficient internal combustion engines today. However, concerns with diesel emissions (nitrogen oxides and particulate matter) have prompted stringent environmental regulations that will become effective in 2007 and 2010. Diesel particulate filters (DPFs) are one of the leading technologies to address these regulations. A DPF is a device that collects particulate matter in the exhaust stream. The high temperature of the exhaust heats the structure and allows the particles inside to break down (or oxidize) into less harmful components. DPFs can reduce emissions of particulate matter, hydrocarbons and carbon monoxide by 60 to 90 percent.

Most DPFs consist of a ceramic honeycomb with hundreds of cell passages partitioned by walls. Each cell passage has a square cell opening at one end and is closed at the other end so that the cell passages are alternately closed at each end. This structure forces the exhaust gases through the porous, thin ceramic honeycomb walls. When the gases carrying the particulates flow through the fine pores of the walls, the particulates are filtered out of the exhaust gases.

High porosity values help attain filtration efficiency greater than 90 percent while reducing gas-flow resistance to prevent affecting engine performance.

Technology

Cummins, Inc., is working with Oak Ridge National Laboratory (ORNL) to develop models to predict the durability and reliability of DPFs. The formulation of such models requires knowledge of the distribution of temperatures and stresses to which DPFs will be subjected during service in addition to how these factors and the service environment affect the thermophysical properties of DPFs as a function of time. This is a challenging goal because DPFs are expected to operate for more than 400,000 miles and to experience possibly thousands of regeneration cycles.

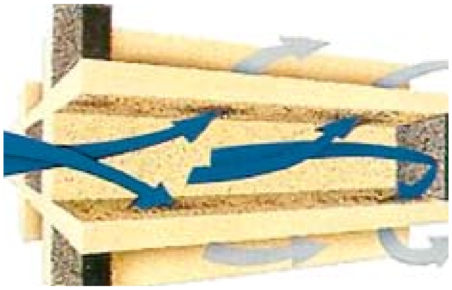

Figure 1. *Cordierite diesel particulate filters.*

Benefits

- Provides property data needed to predict durability of a leading DPF candidate material.
- Helps diesel engines to meet 2007 and 2010 emissions regulations with no fuel penalty.

Fracture toughness and resistance to environmentally assisted crack growth are two key properties that need to be known to predict the reliability and durability of DPFs.

In this project test methods have been developed to determine these properties for porous cordierite, which is one of the leading candidate materials for the manufacture of DPFs.

Test specimens 280-μm thick were prepared, notched, pre-cracked and evaluated by the double-torsion test method to determine fracture toughness. This same test method was used to determine the resistance of porous cordierite to environmentally assisted crack growth at elevated temperatures. The fracture toughness of porous cordierite was found to decrease with temperature from 0.45±0.02 MPa√m at 20°C to 0.36±0.07 MPa√m at 500°C. It was also found that the crack trajectory was significantly influenced by the microstructure of the material, in particular the morphology of pores and their distribution.

Status

Scientists and engineers at ORNL and Cummins are collaborating to develop models to predict the reliability and durability of porous cordierite diesel particulate filters. They are also developing filter regeneration and control strategies that will help meet environmental regulations while preserving the fuel efficiency of future diesel engines

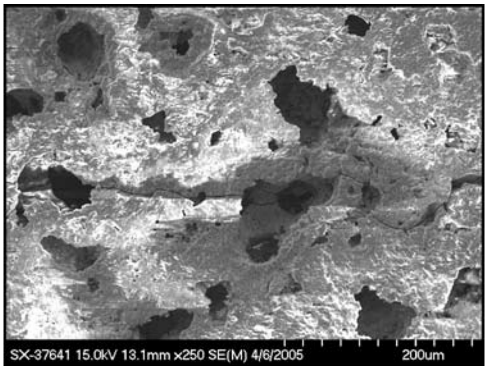

Figure 2. *Scanning electron micrograph illustrating the interaction between the microstructure of porous cordierite and the propagation of cracks.*

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